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GEOLOGY.—*Geothermal gradient of the Mother Lode belt, California.*[1]

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In a paper recently published in this JOURNAL,[2] W. D. Johnston, Jr., maintains on the basis of a recalculation by H. C. Spicer, made according to the method of least squares from the primary data presented in my report on the Mother Lode system,[3] that the geothermal gradient at the Mother Lode is 192.3 feet per degree Fahrenheit instead of 150 feet per degree Fahrenheit as originally given. Unfortunately, however, during the recalculation, two fundamental errors were made which completely vitiate the final result. In the first place temperature observations from two mines (the Plymouth and the Kennedy) situated 10 miles apart were used to compute a gradient, but this procedure is not permissible, as the gradients at the two mines are most likely to be different. In the second place it was assumed that the collars of the shafts of the two mines are at the same altitude. The collar of the Kennedy shaft is approximately 1430 feet above sea level, whereas that of the Plymouth is about 1100 feet. This fact makes the vertical range between the 1600-foot level in the Plymouth mine and the 4200-foot level in the Kennedy differ by 330 feet from what Johnston and Spicer thought it to be.

Johnston says that "Knopf's values for the Central Eureka and the Kennedy mines apparently are based on an assumed value of the mean annual temperature y of the air." The mean annual temperature, however, was not *assumed*, but as stated in Prof. Paper 157, the mean annual temperature at the collar of the Kennedy mine (58.5°) was taken from a 10-year series of daily readings at a Weather Bureau

[1] Received June 1, 1932.

[2] W. D. JOHNSTON, JR. *Geothermal gradient at Grass Valley, California.* This JOURNAL **22**: 267–271. 1932.

[3] ADOLPH KNOPF. *Mother Lode System of California.* U. S. Geol. Survey Prof. Paper **157**: 22–23. 1929.

station maintained at the mine. To be able thus to have an accurately determined mean annual temperature at the collar of the shaft and a temperature determination 4200 feet vertically below is indeed a fortunate combination, and for this reason the geothermal gradient of 153 feet per degree Fahrenheit at the Kennedy mine is held to be entitled to much confidence.

The mean annual temperature at the collar of the Central Eureka shaft, which is 1610 feet above sea level, was estimated to be approximately 58° Fahrenheit, by applying a correction of 0.5° on account of the 180 feet difference in elevation between the Central Eureka and Kennedy mines. By using this figure a gradient of 160 feet per degree Fahrenheit was found to obtain at the Central Eureka mine. At the Plymouth mine no surface temperature records were available, and the gradient of 145 feet was computed from underground data.

There are therefore three determinations of geothermal gradients along the 10-mile segment of the Mother Lode in Amador County, ranging from 145 feet to 160 feet per degree Fahrenheit. In no one of the three sets of determinations are there sufficient data to allow least-square adjustments, and 150 feet per degree Fahrenheit will serve as a round number for the geothermal gradient at the Mother Lode in Amador County.

Johnston has not explained the marked discrepancy between his value of the geothermal gradient at Grass Valley—190 feet—and that earlier determined by Lindgren—122 feet. It would appear worth while for him to show that his data represent a homogeneous set of data, the only kind suitable for least-square computations. In my opinion data obtained from levels in different mines, in rocks of differing conductivities (granodiorite, diabase, and others), in rocks traversed by veins, faults, "crossings" and in places containing standing water, are very heterogeneous, and mathematical manipulation of such heterogeneous data is likely to obscure information of geologic significance.

GEOLOGY.—*Geothermal gradient of the Mother Lode belt, California: A reply.*[1] W. D. JOHNSTON, JR., U. S. Geological Survey. (Communicated by W. H. BRADLEY).

In the preceding paper Knopf offers the following objections to the conclusions contained in a recent paper[2] of mine:

[1] Received June 15, 1932. Published by permission of the Director, U. S. Geological Survey.

[2] W. D. JOHNSTON JR. *Geothermal gradient at Grass Valley, California.* This JOURNAL **22**: 267–271. 1932.

1. "*** temperature observations from two mines (the Plymouth and the Kennedy) situated 10 miles apart were used to compute a gradient, but this procedure is not permissable, as the gradients at the two mines are most likely to be different."

2. "*** it was assumed that the collars of the shafts of the two mines are at the same altitude *** (whereas they) differ by 330 feet.***"

3. "The mean annual temperature, however, was not *assumed*, but *** was taken from a 10-year series of daily readings at a Weather Bureau station maintained at the mine."

4. "Johnston has not explained the marked discrepancy between his value of the geothermal gradient at Grass Valley—190 feet—and that earlier determined by Lindgren—122 feet."

5. "It would appear worth while for him to show that his data represent a homogeneous set of data, the only kind suitable for least square computations."

These objections will be discussed in the following order—2, 3, 1, 4, and 5. The first three refer to Knopf's data for the Mother Lode and the last two to my Grass Valley data.

2. The assumption that the collars of the shafts of the two mines are at the same level was erroneous. From the corrected elevations H. C. Spicer has computed the reciprocal gradient to be 160.5 feet per degree Fahrenheit, as shown in column A of Table 1. This is nearer Knopf's value of 150 feet per degree than my previous erroneous value of 192.3 feet per degree. As the exact elevations of the collars of the Plymouth and Kennedy shafts are not available, Mr. Spicer has also computed geothermal constants based upon the maximum error in the assumed collar elevations of these mines. These values are given in columns B and C of Table 1.

3. The observed mean annual temperature of the air is *not* the mean annual temperature of the rock surface. Numerous observers have found that the air temperature just above the ground surface is from 1 to 10 degrees Fahrenheit lower than the temperature just beneath the ground surface.[3,4] As shown in Figure 1 in my previous paper, the observed mean annual temperature at Grass Valley, a record based upon daily readings during 22 years, is 7 degrees higher than the computed subsurface temperature. Altitude, topographic situation, pre-

[3] J. A. McCutchin. *Determination of geothermal gradients in oil fields located on anticlinal structures in Oklahoma.* Bull. Amer. Petroleum Inst. **205**: figs. 3–9, pp. 58–61. 1930.

[4] A. J. Carlson. *Geothermal conditions in oil-producing areas of California.* Bull. Amer. Petroleum Inst. **205**: figs. 9–84, pp. 121–139. 1930.

TABLE 1.—GEOTHERMAL CONSTANTS FOR THE MOTHER LODE, CALIFORNIA (COMPUTED FROM KNOPF'S DATA BY H. C. SPICER)

Mine	Altitude of collar of shaft	Level	Vertical depth below shaft collar	A				B				C			
				Depth below sea level	Rock temp.	475–2770 ft.		Depth below sea level	425–2795 ft.			Depth below sea level	525–2745 ft.		
						Computed temp.	Observed minus computed		Computed temp.	Observed minus computed			Computed temp.	Observed minus computed	
Plymouth	1,100 (±50)	1,600	1,575	475	72.0	72.0	0.0	425	72.0	0.0		525	72.1	−0.1	
do.	do.	4,000	3,600	2500	86.0	84.7	+1.3	2550	84.8	+1.2		2450	84.5	+1.5	
Central Eureka	1,610	4,400	4,095	2485	83.6	84.6	−1.0	2485	84.4	−0.8		2485	84.7	−1.1	
Kennedy	1,430 (±25)	4,200	4,200	2770	86.0	86.3	−0.3	2795	86.3	−0.3		2745	86.3	−0.3	
Constants						a = 69.08 b = 0.00623 $1/b$ = 160.5 r = ±0.80			a = 69.45 b = 0.00603 $1/b$ = 165.7 r = ±0.70				a = 68.70 b = 0.00644 $1/b$ = 155.4 r = ±0.90		

vailing wind direction, and numerous other factors[5] are responsible for discrepancies of this kind. When the mean annual temperature of the air is used in the computation of a geothermal gradient that value is necessarily an "assumed value," y.

1. An error is probably introduced by the use of temperature data from mines 10 miles apart but it is believed to be of lesser magnitude than the error introduced by the use of the mean annual temperature of the air as the assumed value y.

4. Lindgren's[6] value of 122 feet per degree for the geothermal gradient at Grass Valley is based upon three sets of temperature readings in the Idaho-Maryland Mine,—one in the drain tunnel; a second on level 15, 1,523 feet vertically below the drain tunnel; and a third in a stope 40 feet above level 16.

My values are based upon 22 sets of readings uniformly distributed through a vertical range of 3,600 feet. As all the temperature readings lie on a smooth curve with a maximum difference between the observed and computed values of only ± 0.8 degrees and a probable error of ± 0.26 degrees, the more recent work seems to me to be the more acceptable.

5. Knopf's last point questioning the homogeneity of the Grass Valley data is answered by the distribution of the temperature readings in Figure 1 of my earlier paper. Any marked difference between the conductivity of diabase and granodiorite or the presence of deep artesian circulation along the veins or "crossings" would be shown by an undulation in the depth-temperature curve.

In conclusion it appears that a little more weight should be given to the value of the Mother Lode geothermal gradient of 160 with a possible range of ± 5 feet per degree as computed by the method of least squares from all of the underground data available than to Knopf's value of 150 feet per degree.

[5] E. M. FITTON and C. F. BROOKS. *Soil temperatures in the United States.* Mo. Weather Rev. **59**: 6–16. 1931.

[6] WALDEMAR LINDGREN. *Gold-quartz veins of Nevada City and Grass Valley districts, California.* U. S. Geol. Survey, Ann. Rept. **17**: Pt. 2, 170–171. 1896.

GEOLOGY.—*Stratigraphy and structure of Northwestern Vermont.*—II[1]

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EASTERN SEQUENCE

The rocks of this sequence are well seen a few miles north of Middlebury and near Brandon, and they can also be followed southward

[1] Received June 6, 1932. Published with the permission of the Director, U. S. Geological Survey. Concluded from Vol. 22, No. 13, p. 357, this JOURNAL.

from Rutland to Massachusetts. One formation of the Archean and three formations of the Algonkian are present in this sequence; these are the granite and granitoid rocks of the Archean, and the graywacke, marble, and phyllite of the Algonkian. They are confined to the frontal ranges and hills of the Green Mountains and are seen in most sections into the Mountains. There is an unconformity between these formations and the Cheshire quartzite of the Lower Cambrian, so that in many places the Moosalamoo phyllite is removed and the marble forms the top of the Algonkian. As the unconformity is followed northward the phyllite becomes much thicker, but southward the phyllite, marble, and graywacke all disappear and the Lower Cambrian rests directly upon the Archean granite. This unconformity accordingly is one of the greatest, if not the greatest, in the region.

Nickwaket graywacke.—This formation extends in the Green Mountains from the Canadian border for a considerable distance south of the latitude of Rutland. It invariably forms high ground and mountains, one of which, Nickwaket Mountain, a few miles southeast of Brandon, gives the formation its name. The formation consists entirely of schistose rocks with a large percentage of graywacke and feldspathic quartzite. The schists and schistose coarser beds are composed of variable amounts of quartz, muscovite, biotite, and chlorite with local developments of magnetite. The graywacke beds at the top of the formation are coarse and in many places conglomeratic, while at its base there are important conglomerates. These conglomerates have lenticular forms, being not everywhere present, and they consist of pebbles and boulders of the older rocks, largely quartz, granite and gneiss. Rarely these boulders are as much as two feet in diameter. The best development of this conglomerate, a few miles southeast of Middlebury in the town of Ripton, was described by Dale. The upper graywacke beds are seen in contact with the overlying marble at Forestdale.

Forestdale marble.—There is a sharp change from the graywacke to this marble, the latter being mainly calciferous, while the graywacke contains no calcite. The marble is massive and greatly metamorphosed in most localities, with growth of many silicate minerals. It has colors ranging from white to light gray, buff, and cream mottled, and weathers usually with a marked reddish-brown surface. There are considerable differences in the thickness of the marble with a minimum of perhaps 200 feet in the district northeast of Brandon. Southward the marble thickens until it is two or three times as thick southeast of Brandon, and then thins again to the east of Rutland.

Northward it is fairly continuous to the Canadian border. At Forestdale, five miles northeast of Brandon, there is an excellent section from the upper graywacke conglomerate of the Nickwaket to the basal conglomerate of the Cambrian.

Usually the marble makes low ground, as is conspicuously the case in the valley northward from Forestdale and through Silver Lake. Just below the outlet of Silver Lake there is a very fine section showing the details of the unconformity between the marble and the basal conglomerate of the Cambrian. At this point the Lower Cambrian Cheshire quartzite makes the beautiful Llana Falls.

Moosalamoo phyllite.—The phyllite, a fine-grained black rock, consists mainly of quartz and muscovite with a little biotite and disseminated iron ore. The formation does not change within the region being described except in thickness, as already stated. It ranges from nothing at Llana Falls to a probable thickness of 500 feet upon the south and east slopes of Moosalamoo Mountain, only a mile to the north. It is pinched out in the general latitude of Middlebury but goes still farther to the north.

Cheshire quartzite.—This formation is continuous from Cheshire in northwestern Massachusetts to Canada, except for short stretches of a few miles each where it is cut out by faults. Locally it forms the steep, high front of the Green Mountains and numerous ledges make clear its presence. Huge cliffs are formed by the quartzite at many places, as in Wallingford, 9 miles south of Rutland, or the quartzite may make the entire face of the mountain in a dip slope, as in Hogback Mountain, northeast of Middlebury. This mountain has an anticlinal structure and the quartzite pitches northward under the younger dolomites so that the mountain ends abruptly. The lower part of the formation and the underlying Algonkian formations are shown at Forestdale, 3 miles northeast of Brandon.

By far the greater part of the formation consists of massive, white, vitreous quartzite; this is particularly so in the upper beds. In the middle of the formation thin layers of black slate are interbedded with the quartzite but are not sufficiently well defined to be a regular subdivision of the formation. The chief departure in the lithology of the formation is the basal conglomerate. This is present practically everywhere and occasionally forms a coarse, massive deposit. The conglomerate of this sort consists largely of pebbles of quartz, quartzite, and granite with some additions of marble and slate from the underlying formations. Coarse conglomerate of this nature is found 3 miles southeast of Brandon and resembles strongly the conglomerate at the

base of the Nickwaket graywacke. Doubtless the two were largely derived from the same source. The formation varies considerably in thickness and has a probable maximum of about 800 feet in Wallingford.

Rutland dolomite.—This formation consists almost wholly of dolomite. Its color is usually light or dark gray and it has a fine or medium grain. Most of it is thick bedded though there are a few slabby layers. In the district about 10 miles northeast of Middlebury, in the towns of Bristol and Monkton, the bottom of the formation consists of a mottled light buff or pink dolomite marble which rests directly upon the massive quartzite of the Cheshire. South of that tract the marble beds disappear and the gray dolomite comes down to the Cheshire. In many places there is a transition from the Cheshire quartzite into the dolomite through sandstone and sandy dolomite. This is particularly clear on the south slope of Blueberry Hill, 3 miles north of Rutland, where the syncline of Rutland Valley rises to the north. In the middle of the formation is found a thin horizon of light colored limestones. These appear just north of Rutland but cannot be traced far. Near the top of the formation there is a thick bed of dolomitic sandstone which makes prominent outcrops near Rutland. Below this there are 100 feet or more of dark blue, dolomitic limestone. Fossils were found in this formation in the Rutland Valley by Wolff and Foerste which showed it to be of Lower Cambrian age. A few fossils were found by Walcott in the topmost beds of the Cheshire quartzite, also of Lower Cambrian age.

The strata of this formation, like those of the preceding Cheshire, are very massive and compact and have acted as a unit to minimize the folding; thus the syncline of Rutland Valley is one of the few open synclines in the region. Its western limb is found in Pine Mountain and its eastern limb, which is locally faulted off, appears along the front of the Green Mountains. The strata in the middle of the fold are nearly horizontal. This open fold was thrust westward against the highly deformed beds of the upper part of the sequence.

Danby formation.—This formation is a departure from the usual carbonate deposits of the Valley. There is a great variety in the beds of this formation, but they are separated from the other formations chiefly by the amount of sandstone and quartzite and by their varicolored dolomites. The quartzite beds are composed of clean white sand in separate layers a foot or two thick, interbedded with massive dolomites, like those of the Rutland, and with transitional strata, like sandy dolomites and sandstone. In the usual section the quartzite beds stand out like white reefs above the other layers. Some peculiar

dolomites also are found with a range of colors, including pink, buff, and green. These are very fine-grained and tough and together with the quartzites form ridges. Associated with these beds are thin seams and layers of greenish slate.

The beds of this formation are considerably folded, as would be expected from their variable and thin-bedded character. They usually dip at high angles and exhibit a great variety of small and large folds. This folding makes it difficult to estimate the thickness, but the formation is probably in the vicinity of 300 feet thick.

Wallingford dolomite.—The boundary between the Wallingford and Danby formations is not sharp and is marked mainly by the close of the strong quartzite sedimentation, the variable colors of the dolomite, and the slate beds. It is well exposed in the township of Wallingford, its type locality. The Wallingford dolomite consists mainly of light and dark gray dolomites like those of the Rutland dolomite. With these are interstratified thin beds of dolomitic or quartzitic sandstone of a light gray color. The formation has no other peculiarities and is of about the same thickness as the Danby.

Clarendon Springs dolomite.—This formation consists wholly of fine-grained dolomite of a light gray or dove color, and its type locality is Clarendon Springs, Vt. It differs from the Wallingford dolomite mainly by the absence of sandstone or quartzite. The formation grades upward into Shelburne marble without interbedding or other notable features, and is from 100 to 200 feet thick.

Shelburne marble.—This marble in the Eastern sequence is almost wholly composed of calcite marble, as it is in the Central sequence. The grain of the rock is medium in both sequences, but the color is more variable in the eastern sequence. White with blue mottling and banding are the common colors in the eastern sequence, and in some quarries there are found green bands in the white marble. These features bring out the close folding and flowage patterns in the marble and add to its value as ornamental stone. The quarries are found at short intervals through the entire extent of the formation in the eastern sequence, but they are mainly concentrated around a few centers, such as Brandon, Proctor, and Dorset, which is in the southern part of the state. The marble and associated formations are readily seen in the quarries around Brandon. There is a sharp change, but no visible unconformity, between the Shelburne and the overlying Williston limestone. As was noted under the Central sequence, formations of Middle and Upper Cambrian age are found north of Burlington in the interval between these two formations.

Williston limestone.—This formation in the Eastern sequence differs little from its exposures in the Central sequence. Fossils were found in Brandon which indicated its Upper Cambrian ("Saratogan") age, and very numerous ledges of the formation are to be seen in and around Brandon. The thickness of the formation appears to vary considerably in the Eastern sequence. It reaches its maximum thickness in the region around Brandon but thins materially along the eastern side of the Taconic Range. It is nearly everywhere present, however, and its thinning is due to pinching out locally by folding. It is usually in contact with the overlying Ira slate and the separation between them is sharp. In some places, for instance 4 miles south of Brandon, normal sedimentary contacts show a change within a few inches from deposition of limestone to that of mud.

Ira slate.—This formation is well developed in the town of Ira, which adjoins West Rutland on the south. The formation consists entirely of a dark gray or black slate with very little banding or means of determining bedding, but a few feet of the slate in the lower part of the formation contains gray, siliceous seams. Secondary quartz is developed in these beds and they are tightly squeezed and dissected by folding so that locally the formation resembles a finely banded gneiss. The sedimentary contact between the slate and underlying Williston limestone is sharp, as stated under the description of the limestone. The upper contact of the formation with the West Rutland marble is equally sharp, with a complete change from muddy sediments to pure limestone.

At the north end of the main belt of the West Rutland marble the marble is seen to rest upon the slate in the old True Blue quarry, and the same situation is seen repeatedly in the northerly areas of the marble from three to four miles southwest of Brandon. The slate disappears at the north end of the Taconic Range, but southward it expands into a belt a mile or two in width. There are no measures of the thickness of the formation, but it is probable that it is as much as 700 or 800 feet thick.

West Rutland marble.—This formation is best known from its use as ornamental stone, and West Rutland has long been the principal center of the marble industry. There is a considerable variation in the beds of the marble, and different quarries make a specialty of particular beds. A long line of quarries, old and new, lies along the eastern side of the marble belt. Most of these are now worked as underground mines instead of open-cut quarries. There are also a few quarries on the western side of the belt. The prevailing colors of

the marble are white, more or less banded with dark blue, mottled blue, and light gray. A few beds have a pale green banding, and in the quarries on the west side of the belt mottled, cream colored marbles are produced.

In the two northerly areas of the formation between Brandon and West Rutland the synclines in which the formation lies are shallower than that at West Rutland and only the lower part of the formation appears. In these areas the marbles are, in the main, dark blue, and there is a thin member of blue-banded limestones at the base. This member also appears in the West Rutland area but it is thinner there and poorly exposed. These lower limestones contain a brachiopod fauna and many crinoid stems. The upper marbles, particularly the bluish or blue-banded ones, have many large maclureas which appear best on the sawed surface of the stone. These maclureas were the first fossils found in this region and have always been considered to be of Chazy age. There are several small areas of this marble along the east side of the Taconic Range coming in and out against the Taconic overthrust. These, too, contain fossils and are rather easily identified.

TACONIC SEQUENCE

The rocks of this sequence are found only in the Taconic Range and they form a very striking contrast with the beds of the same age which form the lower ground on the east and west. The sequence consists almost wholly of slates, but it has also one thin formation of limestone and one of quartzite. By means of these two formations in the Lower Cambrian and one of red slate in the Ordovician, the order and structure of these formations can be disentangled. The limestone (Beebe) contains a good Lower Cambrian fauna, and one of the slates has Middle Ordovician fossils. Owing to the intense folding and faulting of this sequence, it has been necessary to follow out individual beds wherever they could be recognized. For this purpose the limestone and quartzite above mentioned were of great service, as well as a few recognizable beds in the lowest formation—the Brezee phyllite. The entire section is exposed south of Stiles Mountain, near the north end of the Taconic Range.

Brezee phyllite.—This formation outcrops around the north and northwest margins of the Taconic Range and is in contact with the underlying limestones and marbles at more places than any other formation. It thus forms the sole along which the Taconic overthrust block moved in coming to its present position. What normally lies beneath the Brezee phyllite is not known because of this overthrusting.

The formation consists almost wholly of slate or phyllite of a dark or bluish-gray color. Much of it is banded with light gray, and its weathered surfaces are apt to have a brownish or dull greenish-gray color. Interbedded with the upper part of the phyllite is a thin calcareous quartzite, from 5 to 10 feet thick, which can be followed for considerable distances and is of much help in working out the fault system. Locally this quartzite passes into a sandy limestone. A few feet below this quartzite there is a zone of limestone lenses, all of which are small. The lowest part of the Brezee contains beds of cherty slate. Most of these are black and they are associated with purple slate of the kind that is so characteristic of the Lower Cambrian in the Taconic Range. These cherty beds resemble some of the Ordovician formations found farther to the southwest, but it is more likely that they represent a facies of the Cambrian. It is very difficult to make an estimate of thickness of this formation, but doubtless it exceeds 500 feet. The formation is named from Brezee Mill Creek, which flows out of the northeast end of the range.

Stiles phyllite.—This formation is rather sharply distinct from the Brezee phyllite. It is much more uniform in composition than the Brezee and its principal variations are those due to metamorphism. The formation consists almost wholly of slate or phyllite, with fairly numerous thin beds of quartzite. The whole formation, including the quartzite beds, has a rather plain greenish aspect due to secondary chlorite. This color is modified on weathered surfaces so as to become a greenish-gray or whitish-gray. Much quartz in thin lenses and veins appears in this formation, especially in its eastern areas, where it is most metamorphosed.

The formation occupies a broad band along the east side of the Taconic Range and curving westward and southwestward around the end of the Range. Along the east side metamorphism has proceeded locally to the extent that the rock is a schist composed mainly of quartz, sericite, and chlorite. The metamorphism is less in going northward and westward around the end of the range, so that at Stiles Mountain the phyllite presents a good average of the condition of the formation. Westward from Stiles Mountain metamorphism is less and the formation may well be called a slate.

The thickness of this formation, like that of the Brezee, is wholly a matter of estimate. Each outcrop is full of minor folds and large folds and faults are noticed. It appears to be perhaps 400 or 500 feet thick at the north, but along the east side of the range it might

be double that thickness, for it forms important mountains and a belt of outcrop several miles wide.

Hubbardton slate.—There is no very sharp division between this slate and the Stiles phyllite, but the latter rather gradually merges up into the slate. The boundary is placed where the small quartzite layers end, which is also the horizon where the special colors of the Stiles end. The Hubbardton slate consists mainly of green slate with a variable amount of the purple slate. In some localities—notably in the western part of the Range—the purple is more common than the green in the upper part of the formation. These beds are very similar to those of the Bull slate which form the chief color horizon for the purple slates. The Hubbardton slate is named from its occurrence in the village of Hubbardton in the north part of the Taconic Range. It is probably about 300 feet thick, but this, too is only an estimate.

Barker quartzite.—This is one of the key rocks of the Taconic sequence, both because it is readily identifiable and because it makes sharp hills and ridges which plainly mark its position. The quartzite has a generally light or white color on weathered surfaces, but usually is more or less green when freshly broken. It varies also in coarseness from a dense rock with very fine grains of quartz to a coarse quartzite and locally a fine conglomerate. The coarser facies contain pebbles of various slates, quartzites, and a little limestone, probably derived from the older Cambrian formations. Possibly it is the same as the coarse quartzite and conglomerate of Bird Mountain a few miles east of Castleton. Barker Hill, for which the quartzite is named, is about 4 miles east of north from Castleton. The quartzite there and in the nearby Wallace Ledge is approximately 100 feet thick. Also it is about as thick in Ganson Hill, just north of the village of Hubbardton. In some places the quartzite thins down until it is barely recognizable.

Bull slate.—This is a comparatively thin formation between the underlying quartzite and the overlying Beebe limestone. The slate is usually of a purplish color more or less mixed with green. The three formations make a distinctive sequence which has helped much in unravelling the structure of the Taconic Range. The Bull slate is named for the quarry on Bull Hill, 2 miles north of Castleton. It is the principal horizon which is worked for the purple and unfading green slates of the slate industry. The principal development of this industry is in the region of Fairhaven, Vermont, and Granville, New York, a few miles to the southwest of Castleton. The slate has a fine, even grain and smooth texture and the banding is so faint that

as a rule it does not affect the smoothness of the cleavage. There are only a few sandstone layers in the formation and occasionally a small bed of limestone appears in the upper part of the slate. No fossils are known from this formation, but its age is fixed by the fossiliferous limestone immediately overlying it.

Beebe limestone.—This limestone, which is only from 5 to 20 feet thick, would in most other regions be called a member of the slate formation; here, however, it is such an exceptional change from the usual character of the sediments and it is so fossiliferous that it is the most important formation of the entire Taconic sequence. It is named for its exposures near Beebe Pond, in Hubbardton, Vt. If drawn according to scale on the map, it would appear only as a line, but it is everywhere present at the proper horizon so far as known. The detailed sequence of formations already mentioned should include also the Hooker slate above the Beebe as being of equal importance. The fossils in this limestone were first found by Walcott in his study of the Taconic System of Emmons, and many collections have been made by later geologists. Although the formation is small, it commonly makes an impress upon the topography either as a line of low knolls or a shelf along the sides of hills made by other formations.

Hooker slate.—This formation is a notably black slate with less cleavage than is usual in this region. So far as is known, no fossils have yet been found in this formation. It appears, however, to be more closely associated with the Lower Cambrian formation than with the Ordovician ones which follow it. It is named from Hooker Hill, 2 miles north of Castleton. The formation in the Taconic Range is only in contact with the Ordovician Poultney slate in one locality, 6 miles southwest of Brandon, where a shallow syncline contains a little of the Ordovician formation. Southwest of the detailed area, however, and in the commercial slate belt around Fairhaven and Granville the contacts with the Hooker and the Ordovician slates are numerous. They are distinctly outlined by the numerous quarries in the Lower Cambrian Bull slate and a similar set of quarries in the Ordovician red slate. These formations run parallel for miles and the contact shows no signs whatever of variation. This is all the more remarkable because at the horizon between the Hooker and the Ordovician slates there is found in northern Vermont a thick section of Middle and Upper Cambrian formations, to say nothing of the Lower Ordovician formations which outcrop within a few miles to the west or north. Thus a significant break in the section appears here with no physical evidence to indicate it. The formations on both sides are all thin, and even a

moderate amount of variation of the plane of hiatus would remove one or more formations.

Poultney slate.—This and the overlying Indian River slate are of Lower Ordovician age as indicated by the graptolites. Graptolites were first found by Walcott in his early work on the Cambrian, and have since been found by many geologists. The Poultney slate, the lowest Ordovician formation, is named for its good exposures in the town of Poultney at the boundary of New York 7 miles southwest of Castleton. The formation consists mainly of gray slate which becomes lighter or even white on exposure. The most prominent feature of the formation is white or light gray chert which appears in very thin seams or in massive beds a foot or so thick. The formation resists erosion and it outcrops abundantly, making hills of considerable height. The normal succession of these beds following the Cambrian is well shown in a shallow syncline in New York just west of Poultney. Around the sides and end of this syncline can be traced the thin formations of the Lower Cambrian and Ordovician with perfect regularity. The fold pitches toward the south so that the youngest formations come in finally in that direction. The succession is almost equally clear for the small area of the formation already noted in the north end of the Range.

Indian River slate.—This is a formation which furnishes the well known red slate of the New York slate industry. It consists mainly of bright red slate with a few thin seams or layers of fine green quartzite; the latter occur only locally. The slate owes its bright red color to the iron oxide which it contains. It is of such a brilliant red that it is quarried a mile southwest of Poultney for use in making red paint. The dust derived from grinding the slate settles in the district surrounding the mill and gives a lurid color to the landscape. The name for the formation is taken from Indian River, a few miles south of Granville, New York, where several red slate quarries are located on the banks of the stream. It overlies conformably the Poultney slate, and is also conformable beneath an unnamed black slate.

Black slate.—The formation which overlies the Indian River slate has not yet received a name. It consists almost entirely of black or dark slate and thus contrasts strongly with the two preceding formations. These three Ordovician formations make a sequence which is as distinctive as the underlying Lower Cambrian sequence. The whole section—Lower Cambrian and Ordovician—is repeated over and over again in the Granville region. The principal feature which distinguishes this slate is the presence therein of numerous graptolites. These and the graptolites in the Poultney slate are assigned by

Ruedemann to the Normanskill horizon of the Albany, New York region.

GREEN MOUNTAIN SEQUENCE

General features.—The rocks of this sequence do not enter the quadrangles herein discussed and in which detailed work has been done. They lie to the east of the main crest of the Green Mountains in the eastern part of the Rutland quadrangle and are there exposed in long, narrow belts closely paralleling the western front of the Green Mountains. They are even more metamorphosed than rocks of the same age and character which appear in the Taconic Range. It is for comparison with the latter rocks that the Green Mountain formations are described. This is essential to an understanding of the Taconic overthrust in this region. The rocks of the Taconic Range, as already stated, are thrust from the east across the rocks of the east half of the Champlain Valley and into their present position. The sole of the overthrust passes upward into the air along the east side of the Taconic Range and does not come down again until far to the east in the middle of the Green Mountains. There, rocks of the same sort as those of the Taconic Range are found resting on the Plymouth marble, which is correlated with the Rutland dolomite of the Eastern sequence. The Plymouth marble rests upon the Cheshire quartzite and the latter upon the Algonkian formations of the Eastern sequence. These Algonkian and Lower Cambrian beds are repeated in parallel synclines which bridge across the anticlinorium of the Green Mountains in the northern part of the Rutland quadrangle. Southward from West Bridgewater, which is in the latitude of Rutland and about 18 miles to the east, the Plymouth marble forms a deep, narrow valley with a general southerly trend, bordered on the west by the Cheshire quartzite and on the east by the overlying Lower Cambrian schists. These are terminated a few miles east of West Bridgewater by a fault which extends far to the north and south. South of Ludlow, Vt. the Lower Cambrian formations are cut out along this fault, but they reappear still farther south and form the Stamford Valley for a few miles north of North Adams, Mass. The great fault there passes under the foot of Hoosac Mountain and thence far to the south in Massachusetts. This fault is the root of the Taconic overthrust as now delineated in the Taconic Range, and the two parts of it are barely one mile apart in Mt. Greylock and Hoosac Mountain. This part of the fault has recently been determined and mapped by Prindle in Massachusetts and for some distance north of Bennington, Vermont, while the northern part of the fault in the Taconic Range was first

proved and announced by the present writer in 1912. The entire length of the fault in Vermont and Massachusetts has been examined by the writer. The following brief description of the rocks of the Green Mountain sequence will serve to show their parallelism with those of the Taconic Range.

Pre-Cambrian rocks.—Formations of this age continue eastward from the Champlain Valley across the Green Mountains and differ little from place to place. In the latitude of Rutland the uppermost Algonkian formation—Moosalamoo phyllite—is not present, but farther north it comes in beneath the basal unconformity of the Cambrian. The description of the Algonkian formations of this section is practically the same as for the Eastern sequence.

Cheshire quartzite.—This Lower Cambrian formation consists mainly of quartzite, but it is thinner and more thinly bedded than the same quartzite of the Eastern sequence. The basal conglomerate of the formation is well shown, particularly in Sherburne, 12 miles northeast of Rutland, and there is the same central division of thin beds, now schists, parting the quartzites. A similar thinning and a similar subdivision may be seen in Stamford Mountain along the Massachusetts border.

Plymouth marble.—Exposures of this formation are few, as it is easily soluble and underlies the deep valley which bisects the Green Mountains in this region. The formation is composed chiefly of dolomitic marble which is grey or darkly mottled. In the town of Plymouth limestone conglomerates appear in the formation, some of which have been used for ornamental stone known commercially as "Plymouth breccia." The marble is much folded and in places probably faulted so that its true thickness is unknown. This formation is much thinner than the Rutland dolomite of the Eastern sequence with which it is correlated.

Albite schist.—Overlying the marble is a fairly thick body of dark schist or phyllite. Most of this consists of sericite and quartz sprinkled with iron oxide dust, but in many places it is speckled with secondary crystals of albite. Locally these predominate and give a pepper and salt appearance to the rock. There appears to be repetition of these schists with the marble, but it seems more probable that this is due to folding or faulting than to original deposition.

Pinney Hollow schist of Perry.—This formation was recently described by Perry as overlying the albite schist. The exposures in Pinney Hollow in the town of Plymouth appear to be traversed by faults so that the section there is not certain. In West Bridgewater, a few miles to the north, an excellent section of the formation is exposed

which might well have been taken as the type locality. The formation is uniform throughout and consists almost entirely of chloritic, muscovite schist. This has a pale greenish color when fresh and on the weathered outcrops becomes greenish or whitish-grey with many rusty colored beds. Thin quartzite layers are found in the schist in many places and there is much secondary quartz in the lenses and veins. This formation is the precise duplicate of the Stiles phyllite of the Taconic sequence and like the latter forms high ground or mountains.

Quartzite.—Overlying the Pinney Hollow schist is a thin formation of quartzite of a dark bluish color but which weathers light gray or white on exposure. No name has been given to this formation for it has not been worked out in detail.

Ottauquechee phyllite of Perry.—This formation of Perry's marks an abrupt change from the preceding quartzite and green schist. It consists almost wholly of dark colored or black phyllite in which bedding is rarely seen. The formation is probably rather thick and similar in bulk to the Pinney Hollow schist of Perry. It appears to be terminated at the top by a fault, so that the nature of the formations immediately following is not evident here. Not far to the east—in the central part of the State—other Cambrian formations are reported, and above them several formations of phyllite and limestone in which Ordovician fossils have been found. Thus far, detailed work has not progressed so far that the relations of these groups can be stated.

GEOLOGY.—*Notes on the Puerco and Torrejon formations, San Juan Basin, New Mexico.*[1] C. H. DANE, U. S. Geological Survey.

During the summer of 1928 the writer was engaged in mapping for the U. S. Geological Survey the coal beds of the Upper Cretaceous Fruitland and Mesaverde formations in the southern part of the San Juan Basin, New Mexico. Plane table mapping was carried only to the top of the Ojo Alamo sandstone (which is in the opinion of the writer the uppermost Cretaceous formation of the region), but a reconnaissance map was made of the area to the north, where the overlying Puerco and Torrejon formations of Eocene age are exposed. The base of the still higher Wasatch formation was also sketched. (Figure 1.) Although the field study was thus limited, it seems worthwhile to correct some errors in the literature on the stratigraphy of the Puerco and Torrejon formations and point out that the Puerco formation may be present along the Rio Puerco, although the distinctive verte-

[1] Received May 31, 1932. Published by permission of the Director of the U. S. Geological Survey.

brate fauna by which alone it is recognized has not yet been found there.

The history of the names Puerco and Torrejon has been traced in detail by Gardner[2] and Bauer[3] and summarized by Reeside.[4] The name Puerco was applied by Cope[5] to the series of beds on the Rio Puerco which are now supposed to include both the Puerco and the overlying Torrejon formations. Although he collected no fossils from these beds at the type locality, numerous vertebrate fossils were subsequently collected for him in the region west of the Puerco River

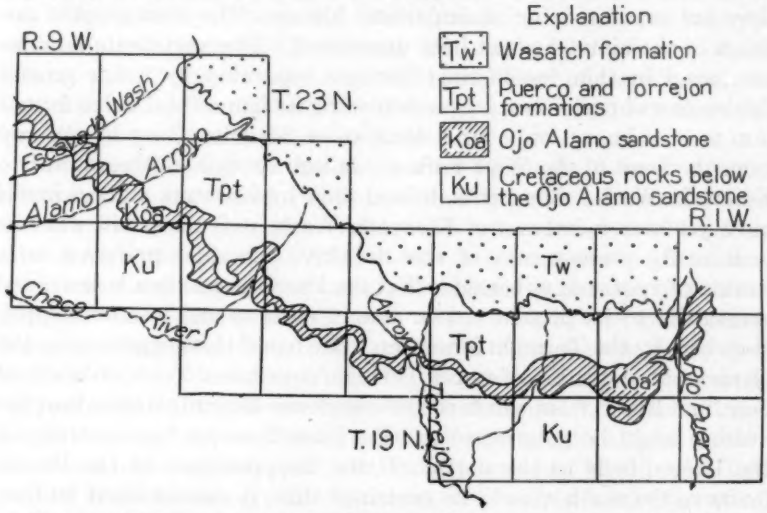

Fig. 1.—Geologic map showing distribution of Ojo Alamo sandstone and Puerco and Torrejon fomations between Escavada Wash and Rio Puerco, New Mexico.

from what he believed to be the equivalent of his Puerco beds. He described these fossils as the Puerco fauna. Wortman[6] later recognized two distinct vertebrate faunas in collections made near Arroyo Torrejon and farther west. For the beds yielding the younger fossils he

[2] J. H. GARDNER. *The Puerco and Torrejon formations of the Nacimiento group.* Jour. Geology. **18**: 702–812. 1910.

[3] C. M. BAUER. *Stratigraphy of a part of the Chaco River Valley.* U. S. Geol. Survey Prof. Paper **98**: 276–277. 1916.

[4] J. B. REESIDE, JR. *Upper Cretaceous and Tertiary formations of the western part of the San Juan Basin.* U. S. Geol. Survey Prof. Paper **134**: 35. 1924.

[5] E. D. COPE. *Report on the geology of that part of northwestern New Mexico examined during the field season of 1874.* Chief Eng. Ann. Rept. for 1875, pt. 2, appendix G 1. 1008–1017. 1875.

[6] Cited by H. F. OSBORN and CHARLES EARLE. *Fossil Mammals of the Puerco beds, collection of 1892.* Am. Mus. Nat. Hist. Bull. **7**: 2. 1895.

proposed the name Torrejon,[7] from exposures near the head of Arroyo Torrejon, and retained the name Puerco for the lower beds. His definitions have been since generally accepted. Gardner[8] used the term Nacimiento group (from the town of that name on the Puerco River, now known as Cuba) to include the two formations. This name has not been widely used.

The Puerco and Torrejon formations are so similar in lithology that no separation between them has been made on this basis, although the faunas are so different that vertebrate paleontologists believe that they are separated by an important hiatus. The stratigraphic position of the hiatus has not been discovered. The vertebrate remains are found in thin fossiliferous horizons separated by much greater thicknesses of barren beds. As defined by its fauna the Puerco formation is now known only for a distance of 35 miles along its outcrop from the head of the West Fork of Gallego Arroyo southeastward to Escavada Wash. Since it is defined only by its fauna and no fossils have yet been found east of Escavada Wash, it is uncertain whether it is really present east of that locality. Reeside[9] preferred as a working hypothesis to consider that the Puerco formation is restricted practically to its present known area of outcrop and was overlapped elsewhere by the Torrejon formation. He based this suggestion on the demonstrated overlap of upper Torrejon over lower Torrejon north of San Juan River, from which the inference was logically drawn that the overlap might be progressive and the lower Torrejon have overlapped the Puerco beds to the north. If the disappearance of the Puerco fauna to the north were to be explained thus, it seemed likely to Reeside that a similar overlap might explain the non-discovery of the Puerco fauna east of its known extent. Some support for this suggestion existed in the supposed thinness of the barren zone beneath Torrejon fossils on Arroyo Torrejon and the Rio Puerco, and the failure of careful search to disclose Puerco fossils near the Rio Puerco. The supposed thinness of the barren zone in this eastern area was based upon the sections given by Gardner[10] which have been subsequently modified and interpreted both by Sinclair and Granger[11] and by Reeside.[12]

[7] Cited by W. D. MATTHEW. *A revision of the Puerco fauna.* Am. Mus. Nat. Hist. Bull. **9**: 260. 1897.

[8] J. H. GARDNER. *op. cit.* 713.

[9] J. B. REESIDE, JR. *op. cit.* 35–36.

[10] J. H. GARDNER. *op. cit.* 717–723.

[11] W. J. SINCLAIR and WALTER GRANGER. *Paleocene deposits of San Juan Basin, New Mexico.* Am. Mus. Nat. Hist. Bull. **33**: 308. 1914.

[12] J. B. REESIDE, JR. *op. cit.* Pl. 2.

But the sections given by Gardner for the Arroyo Torrejon and Rio Puerco areas are certainly much too thin. As shown by his map, photograph, and sections, he interpreted the Ojo Alamo sandstone in the vicinity of the Rio Puerco as a sandstone in the lower part of the Puerco formation, and he included in the Puerco the beds below the Ojo Alamo and down to the Lewis shale. These beds are now known to include Kirtland shale, Fruitland formation, and Pictured Cliffs sandstone. If from the Rio Puerco section given by Gardner 281 feet of beds at the top which are probably to be referred to the Wasatch and 179 feet of Ojo Alamo and older Cretaceous beds at the base are excluded there remains 379 feet for the combined thickness of the Puerco and Torrejon formations. The thickness of the Puerco and Torrejon formations at this place however, is actually more than 630 feet as is shown by the section in Table 1.

Gardner correlated the fourth member above the base in his Rio Puerco section (now known to be Ojo Alamo sandstone) with the third member above the base in his Arroyo Torrejon section, a 30 foot tan colored sandstone, and stated that this is a very persistent horizon marker and was traced continuously from the Nacimiento Mountains to the Arroyo Torrejon and beyond. This 30-foot tan-colored sandstone is quite surely Ojo Alamo and the 80 feet of shale below it is Kirtland shale. Accordingly Gardner's Arroyo Torrejon section allows only 240 feet for the combined thickness of the Puerco and Torrejon formations. An estimate by the writer, based on known contact elevations and locations and a minimum allowance for dip of 1 foot per 100 horizontally, gives a thickness, believed to be conservative, of 700 feet for the combined Puerco and Torrejon formations in the vicinity of Arroyo Torrejon. This does not seem excessive compared with the incomplete section of 570 feet of Puerco and Torrejon measured at the head of Ojo Alamo Arroyo, in T. 24 N., R. 11 W., by C. M. Bauer and J. B. Reeside, Jr.[13]

Sinclair and Granger[14] in correlating their sections with the sections published by Gardner state that "In the Arroyo Torrejon section of Gardner the full thickness of the Puerco is certainly not exposed. Of the 210 feet referred by him to that formation 100 feet is now known to belong to the Torrejon because Torrejon fossils in abundance are found at the point indicated in the section, 100 feet below his Puerco-Torrejon contact." The point indicated in the section is just above the 30-foot tan-colored sandstone which is most probably the Ojo Alamo sand-

[13] J. B. Reeside, Jr. *op. cit.* 67.
[14] W. J. Sinclair and Walter Granger. *op. cit.* 308.

stone. Furthermore, on the same page they speak of "the discovery of Torrejon fossils immediately above the 30 foot bed of sandstone (third member above the base in the Arroyo Torrejon section)." If these correlations were accepted, the Puerco would be missing from

TABLE 1—SECTION OF PUERCO (?) AND TORREJON FORMATIONS, EXPOSED IN THE FRONT OF CUBA MESA, IN THE NORTHEASTERN PART OF T. 20 N., R. 2 W. MEASURED BY C. B. HUNT.

	Feet	Inches
Wasatch formation:		
Sandstone and conglomerate		
Puerco (?) and Torrejon formations:		
Sandstone, argillaceous, tan	70	
Sandstone, light tan	12	
Sandstone, argillaceous, tan in lower part, gray above	48	
Clay, in alternating light and very dark gray bands	30	
Sandstone, gray, massive and cross bedded	12	
Clay, in alternating light and very dark gray bands	29	
Sandstone, tan, cross bedded	14	
Clay, sandy, gray, with some bands of dark gray clay	20	
Sandstone, gray, cross bedded	18	
Clay, in alternating bands of variable thickness, light and very dark gray	12	
Sandstone, gray, cross bedded	32	
Clay, in alternating bands of light and very dark gray	36	
Sandstone, gray, cross bedded	10	
Sandstone, with spheroidal concretions of dark manganiferous (?) material, more than a foot in diameter	3	
Sandstone, gray, cross bedded	10	
Clay, in alternating light and dark gray bands	70	
Sandstone, fine grained, light gray, with dark manganiferous (?) concretions	18	
Clay, in alternating light and dark gray bands	24	
Sandstone, fine grained, light gray	5	
Clay, in alternating light and dark gray bands, white at the base	26	
Coal	0	2
Clay, banded light and dark gray	15	
Shale, dark carbonaceous, not a persistent bed	0	6
Coal, a bed locally as much as one foot thick and continuous for three quarters of a mile	0	8
Clay, dark gray with some lighter gray bands	18	
Sandstone, fine grained light gray, of variable thickness	7	
Clay, light and dark in alternating bands	43	
Concealed for the most part but probably banded clay	50	
Thickness of Puerco (?) and Torrejon	633	4
Ojo Alamo sandstone:		
Sandstone and conglomerate		

Arroyo Torrejon eastward. It appears, however, that Sinclair and Granger were misled by the erroneously thin section given by Gardner into believing that the lower fossil horizon, 100 feet below the upper one, would fall just above the 30 foot sandstone (now recognized to be

the Ojo Alamo). However, they further state that the two Torrejon fossil horizons are exactly 100 feet apart and that both horizons were traced from the East Fork of Arroyo Torrejon to the west branch of Kimbetoh Arroyo. Inasmuch as the Arroyo Torrejon collecting localities located on their sketch map and described in their text are in the face of the cliff capped by the basal sandstone of the Wasatch it appears most likely to the writer that both Torrejon horizons are actually well above the Ojo Alamo sandstone.

Accordingly the writer believes that in the Arroyo Torrejon section there are probably 450 feet of beds below the lowest Torrejon fossils, in which quite possibly there are beds equivalent to the Puerco beds farther west. Because the combined thickness of beds of Puerco and Torrejon lithology along the Rio Puerco is less than 100 feet thinner than the probable thickness of the Puerco and Torrejon formations on Arroyo Torrejon, it further appears that an equivalent of the Puerco formation may also be present along the Rio Puerco.

PALEONTOLOGY.—*Fossil Pinnotherids from the California Miocene.*[1] MARY J. RATHBUN, U. S. National Museum.

Mr. E. W. Galliher of the Hopkins Marine Station has sent to the National Museum a number of specimens of Pinnotherid crabs from the type locality of the Monterey formation at Pacific Grove, as follows:

Specimens 1–5, from the top of hill with elevation of 610 feet about 1 mile W. of N. of Loma Alta and stratigraphically 700 feet approximately above the base of the type section of the Monterey formation.

Specimens 6–9, 11, 12, from the top of Loma Alta (northerly peak) and stratigraphically about 1000–1300 feet above the base of the type section.

The specimens are embedded in Monterey shale of a pinkish cream color. The most abundant species, *Pinnixa galliheri*, varies in color from ochraceous buff to raw sienna; *Parapinnixa miocenica*, from ecru drab to bistre; while the single specimen of *Pinnixa montereyensis* is mummy brown.

Pinnixa galliheri, new species

Carapace in shape akin to *P. faba*,[2] the anterior margin advanced at middle, lateral margins arcuate, continuous with the antero-lateral curve; length a little more than 2/3 of width; greatest width a little in advance of middle; surface finely and closely pitted or reticulate. Gastric region defined; mesogastric almost an equilateral triangle, a pit at each angle, a groove extending

[1] Published with the permission of the Secretary of the Smithsonian Institution. Received May 7, 1932.

[2] M. J. RATHBUN. *A recent species, Alaska to San Pedro, California.* Bull. U. S. Nat. Mus., 97: 142, pl. 31, figs. 1–4, and synonymy. 1918.

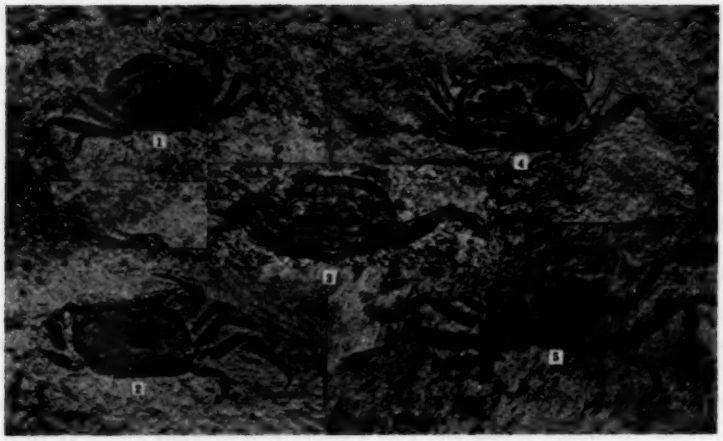

Fig. 1.—*Pinnixa galliheri*, No. 4, holotype, dorsal view showing half of outer surface, x 3. Fig. 2.—*Pinnixa galliheri*, No. 12, dorsal view for legs, x 3. Fig. 3.—*Pinnixa galliheri*, No. 11, ventral view for abdomen, x 3. Fig. 4.—*Pinnixa galliheri*, No. 6, ventral view for outline of carapace, x 3. Fig. 5.—*Pinnixa galliheri*, No. 5a, largest specimen, dorsal view, x 3.

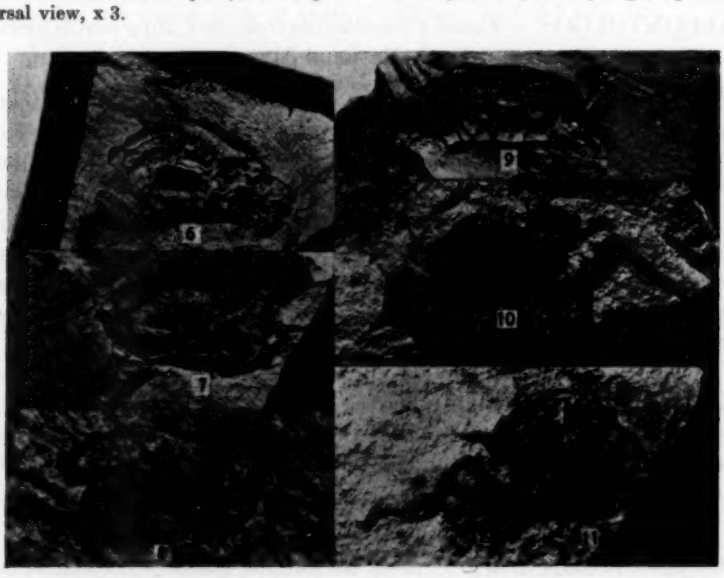

Fig. 6.—*Parapinnixa miocenica*, No. 9, dorsal view, x 3. Fig. 7.—*Parapinnixa miocenica*, No. 1a, ventral view, outer layer preserved, x 3. Fig. 8.—*Parapinnixa miocenica*, No. 3, ventral view for sternum and abdomen, x 3. Fig. 9.—*Parapinnixa miocenica*, No. 1b, holotype, dorsal view (inner surface), x 3. Fig. 10.—*Parapinnixa miocenica*, No. 5b, dorsal view, dark-colored, x 3. Fig. 11.—*Pinnixa montereyensis*, No. 8, holotype, ventral view, showing shape of abdominal cavity of ♂, x 3.

from its anterior end to the margin of the front. Cardiac region faintly outlined.

Chelipeds stouter than legs, fingers nearly as long as palms, upper margin of dactylus strongly curved. Ambulatory legs increasing in length from the first to the third, fourth leg much the smallest; meropodites narrow, the first one recurved, 5 times as long as wide, the second straight, equally wide, 6 times as long as wide, the third wider, nearly a fourth longer than the second, its length 4.4 times its greatest width; carpus-propodus as long as merus, propodus tapering distally. Fourth leg very feeble, reaching if extended about to end of merus of third pair; carpus, propodus and dactylus subequal in length, dactylus with straight margins. Sternum irregularly punctate. Male abdomen gradually narrowing distally, terminal segment broadly rounded.

Measurements.—Length of carapace 7.8, width 11.8 mm.

Specimens.—Nos. 2, 4 (holotype), 5*a*, 6, 7, 11, 12.

Pinnixa montereyensis, new species

Only the ventral surface of the single specimen is exposed. Carapace of ♂ narrow, approximately 8 mm. long and 10 wide. Posterior margin nearly straight, anterior and lateral borders forming a single arch. Abdomen tapering gradually to the terminal segment where it widens, the segment having arcuate sides, projecting laterally and ending in a shallow median point, as in *P. transversalis.*[3] Of the ambulatory legs, the third is longest, second next, first and fourth subequal; a terminal spine above on the merus of the first leg.

Specimen.—No. 8, holotype.

Parapinnixa miocenica, new species

General shape of carapace similar to that of the Recent *P. nitida* (Lockington)[4] from the Gulf of California. Carapace nearly twice as wide as long, widest in anterior half, anterior margin nearly transverse, antero-lateral angles broadly arcuate; surface, so far as exposed, very finely punctate; a deep pit at the posterior corners of the mesogastric region. Chelipeds strong; carpus with arcuate outer line; movable finger longer than palm. First ambulatory leg long and strong; merus widening from proximal to distal end; propodus diminishing gradually to distal end, about 2½ times as long on upper margin as its proximal width. Male abdomen occupying ⅓ the width of proximal end of sternum and gradually tapering; tip unknown.

Measurements.—Estimated length of carapace 5.2, width 9 mm.

Specimens.—1*a*, 1*b* (holotype), 3, 5*b*, 9.

[3] *op. cit.*, p. 132, fig. 76.

[4] *op. cit.*, p. 108, fig. 58a.

PALEOBOTANY.—*Fossil stipules of Platanus.*[1] EDWARD W. BERRY, Johns Hopkins University.

The presence of stipules in connection or association with fossil leaves is always an item of especial interest, since they are exceedingly rare as fossils. This is possibly due to the fact that so often they attain their best development on spring shoots which last are less

[1] Received June 2, 1932.

likely to become fossilized than deciduous leaves. It might be expected that fugaceous stipules would frequently be preserved in spite of their sometimes delicate nature, and possibly many of not especially characteristic form have been passed by, but as a matter of fact very few have been recorded, and in many years experience in handling large quantities of fossil leaves I do not recall having found detached stipules except in the case of Salix[2] and the present instance.

Many years ago the late Lester F. Ward gathered together all of the references to stipular-like lobes or appendages in the genus Pla-

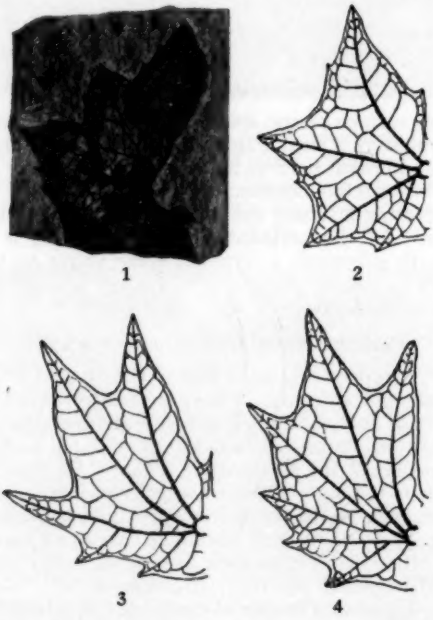

Fig. 1—Fossil stipule in the genus Platanus, probably referable to *Platanus dissecta* Lesquereux. Figs. 2, 3, 4.—Examples of stipules of *Platanus occidentalis* Linné.

tanus, and in several papers[3] advocated the idea that in this genus the modern type of stipules had been derived from ancestral basal lobes of the leaf lamina. None of Ward's examples are, however, like the modern type, such as is the specimen which is the subject of the present note.

[2] E. W. Berry. U. S. Geol. Survey Prof. Paper **154**: 242, pl. 52, fig. 6; pl. 64, fig. 9. 1929.

[3] L. F. Ward. U. S. Nat. Mus. Proc. **11**: 39–42, pl. 17–22. 1888; Am. Nat., Sept. 1890: 797–810, pl. 28.

In earlier years I collected many specimens of *Platanus occidentalis* which illustrated Ward's hypothesis, and at that time made large collections which seemed to show a parallel ancestry for the stipules in the genus Liriodendron.[4] If this assumption is true, the origin of stipules in Liriodendron must have taken place during Upper Cretaceous time because what appear to be stipules of the normal modern type are found in the Atane beds of western Greenland.[5, 6]

The fossil Platanus stipule comes from the upper Miocene Latah formation outcropping in a cut of the S. P. & S. Ry. at Spokane, Washington, and was collected by E. E. Alexander. It comprises the specimen shown in Figure 1 and a part of its counterpart, and may be described as follows: Reniform in general outline with five principal lobes, of which the uppermost is the largest. Lobes conical, pointed. Sinuses shallow, in no case extending as much as half way to the point of attachment, the two upper narrow, the two lower wide and scarcely perceptible. Margin with a few irregularly spaced tiny serrate teeth. Length about 4.25 centimeters. Maximum width about 2.25 centimeters. Texture firm. Veins well marked.

There are minor differences only between the fossil and some of the modern form of stipules in our common eastern *Platanus occidentalis*. Others have either less extended or more extended lobes. The venation of the fossil differs in but a single feature from that of the recent forms and this is that the midvein of the superior lobe is a branch of the midvein of the second lobe, a feature which I have not seen in modern stipules of Platanus although it may well occur in certain cases, and is a feature of no great significance in any event, as may be seen by the variation in the primary or secondary nature of the midveins of the inferior lobes.

The normal stipules in both the California *Platanus racemosa* Nuttall and our eastern *Platanus occidentalis* Linné may be entire or dentate, and on especially vigorous shoots of saplings and from cut stumps are frequently as large or larger than the fossil. The modern, and presumably the fossil stipules, are normally united laterally to form a perfoliate affair attached by a basal tube which surrounds the shoot above the insertion of their respective leaves. Five or six of the principal veins extend in a parallel manner to the base of this tube. Rarely are the two members of a stipular pair exactly alike in outline, and one member of the pair is usually considerably smaller than the other.

[4] E. W. Berry. Bull. Torrey Bot. Club **28**:. Sept. 1901.
[5] O. Heer. Fl. Foss. Arct. **6**: part 2: 90, pl. 23, fig. 8. 1882.
[6] E. W. Berry. Torreya **3**: 129, fig. 4. 1903.

The question of the particular leaf species to which the fossil stipule belongs can be settled with some degree of certainty. Three nominal species of Platanus have been recorded from the Latah formation. These are the common and widespread *Platanus dissecta* Lesquereux, the somewhat protean *Platanus aspera* Newberry, and *Platanus appendiculata* Lesquereux. The last is of somewhat doubtful identity in the Latah and was based upon a single incomplete specimen with a perfoliate basal lobe. The present fossil stipule could not possibly have belonged to *Platanus appendiculata* unless it is conceded that it had both basal lobes and normal stipules at the base of the petiole, which is possible but not probable. The character of the dentition of the fossil stipule would seem to me to exclude *Platanus aspera* from consideration, thus leaving *Platanus dissecta*, which is the commonest Miocene and the commonest Latah species, as the probable parent.

I have seen no modern stipule precisely like the fossil, but have figured three stipules of *Platanus occidentalis* and it will be seen that, although not identical, there is much less difference between the fossil stipule and Figure 2 of *occidentalis* than there is between Figure 2 and the extreme dentate forms of *occidentalis* shown in Figures 3 and 4. It is at least clear that the modern type of stipule in this genus was in existence as early as the late Miocene, and that the stipules have undergone but slight and certainly no essential change since Miocene time.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

GEOLOGICAL SOCIETY

487TH MEETING

The 487th meeting was held at the Cosmos Club, March 9, 1932, President F. E. MATTHES presiding.

Program: G. F. LOUGHLIN: *The results of recent geologic work at Cripple Creek, Colorado.*—The speaker confined his remarks mainly to the structural development of the denuded Cripple Creek volcano, which was formed by the explosive eruption of phonolitic and related material through pre-Cambrian granites, schist, and gneiss. The principal causal factors were the settling of the fragmental material in the crater and intermittent regional compression. Settling was first illustrated by the local explosion pipe known as the Cresson "blowout," which has an elliptical form and tapers downward into two "roots" that have an easterly alignment.

The main crater was developed along a complex network of fissure zones, the principal one trending east and southeast. Exposures in the deeper mine workings show that it also tapers downward with increasingly elongate form and probably separates into several roots. Settling developed steeply dipping fissure systems normal and parallel to the walls of the elongate parts, and also

gently dipping fissures or "flats." Regional compression developed minor shear zones in and around the volcanic mass, many of which coincided in the general direction with the fissures due to settling. The more profound of these shear zones determined the courses of dikes and ore deposits, which, especially in the shallower part of the mass, spread along the "flats." (*Author's abstract.*)

Discussed by Mr. L. H. SMITH.

SIDNEY PAIGE: *The origin of the Vredefort dome.*—In a recent publication[1] Hall and Mollengraaff describe and discuss a remarkable, perhaps unique, geologic structure. The Vredefort granite, a circular mass about 40 kilometers in diameter is surrounded by a girdle of *overturned, metamorphosed,* sedimentary and igneous rocks. The inversion of the sediments involves not less than 10,000 meters of strata and the metamorphism affects in places as much as 3000 meters of strata. Basic rocks invade the peripheral sediments in sill-like masses and also are found cutting the granite parallel to the contact and in places normal to it.

The authors conclude that the Vredefort granite is not intrusive into the sediments that surround it, but is the ancient floor upon which the sediments were laid down, and that the structure as observed today is due to *centripetal pressure* the nature and cause of which is frankly admitted to be unexplained. The authors are the first to admit that many facts of observation are open to divergent interpretations. There are many such aspects of the problem that cannot be discussed here, or even mentioned, but are apparent on a careful study of the monograph and which the writer hopes to consider at another time.

The writer believes that the facts presented by Hall and Mollengraaff support the following thesis:—(1) That the ancient floor of granite and schist upon which the Witwatersrand beds were laid down was invaded by a later granite; that the invaded floor was heated to a point where plasticity prevailed and the invaded floor and the invading granite acted essentially as a relatively stiff magma; that the circularity of the intrusion was due to this fact alone; that the vertical upward movement of the re-melted, invaded, floor created a great *distensional* dome; that continued upward movement brought about faulting at a late stage, along radii of the dome in the zone of fracture and that ultimately these faults extended to the base of the sedimentary column; that low angle concentric shears developed; that in view of these structures the magma collapsed laterally which was the direct cause of the overturned structures observed today. (2) That the Vredefort domical structure is but one of a number of anticlinal structures, viz;—the Johannesburgh, Ventersdoorp and Heidleberg anticlines, all *causally related*; that the related anticlines are equally due to forces acting vertically upward, and producing *distension* of the crust; and that the lack of overturning except at Vredefort is to be explained by the fact that at other places the basement floors were not invaded or re-heated to any substantial degree; that the motivating force of all these uplifts was *isostatically* related to the enormous downwarp of the Bushveldt complex, immediately to the north; that the broad picture suggests that an immense crustal downwarp in one area resulted in subterranean transfers of material, re-heating of an ancient basement, invasion of the basement, distension of the crust by vertical uplift on a grand scale, with local violent

[1] HALL, A. L., and MOLLENGRAAFF. *The Vredefort Mountain Land in the Southern Transvaal and the Northern Orange Free State.* Ver. K. Akad. van Wetenschappen Amsterdam (Tweede Sectie) Deel **24**: No. 3. 1925.

compression of a thick series of sedimentary rocks owing to their displacement by an essentially igneous mass. (*Author's abstract.*)

Discussed by Messrs. JOHNSTON and RUBEY.

D. F. HEWETT: *The habitat of manganese minerals.*

Discussed by Messrs. HESS, L. H. SMITH, LOUGHLIN, C. S. ROSS, and SCHAIRER.

488TH MEETING

The 488th meeting was held at the Cosmos Club, March 23, 1932, President F. E. MATTHES presiding.

Informal communications: Mr. F. L. HESS described the occurrence of hydrocarbons in samples of pegmatites from Parry Sound, Ontario, Canada. The partly dried oil or hydrocarbon occurred in cracks in feldspar crystals and some of the globules bore minute crystals of pyrite and quartz. A much harder hydrocarbon, nearly pure carbon, called thucholite appears to have replaced uranonite.

P. F. SHENON described some platinum placer concentrates from Waldo, Oregon which contained small rings. These rings proved upon spectral analyses to be fragments of tungsten filaments from electric light bulbs.

W. D. JOHNSTON, JR. showed tables and graphs of geothermal data and the adjusted geothermal gradient of Grass Valley, Cal. He compared this gradient with that observed in other deep mines.

Discussed by G. S. RICE and W. H. BRADLEY.

H. S. LADD: *The Melanesian Continent.*—The hundreds of islands which are concentrated in the southwest quarter of the Pacific Ocean may be divided into two groups, the oceanic and the continental. The latter, showing plutonic and metamorphic rocks in addition to the volcanic rocks and limestone which characterize the oceanic islands, all lie within a line drawn from Yap southeastward through Turk, New Ireland, the Solomon Islands, and Fiji to Tonga, thence southwestward through the Kermadecs to include New Zealand and certain of its outlying islands. Fossiliferous Paleozoic and Mesozoic rocks have a wide and somewhat systematic distribution within the area thus outlined, indicating that large parts of it have been above the ocean depths for much of geologic time.

The distribution of the arcs and fore-deeps suggests that this area, whose boundaries roughly coincide with those of Melanesia, was built up originally as a series of folded mountains. There is much evidence however, particularly from Fiji, Tonga, and New Zealand, to support the hypothesis that block faulting, with the extrusion of volcanic material along some of the major fault planes, was initiated prior to the Miocene and is largely responsible for the present distribution of land and sea. (*Author's abstract.*)

Discussed by Mr. MATTHES.

C. W. WRIGHT: *The 1931 Glacier Bay expedition.*—The writer showed the present positions of the glaciers and extent of the ice cap within the Glacier Bay region, S. E. Alaska, and also the outline of the ice field at the time he and his brother, F. E. Wright, mapped the area 25 years ago. The tidewater glaciers have all receded, some of them several miles up the inlets, and certain of those that were at tidewater in 1906 are now a mile or more back on the land, due in part to the recession but largely to the advancing delta deposits. At the Rendu Glacier, with a drainage area of 30 square miles, it was estimated that 70 million cubic feet of material are being deposited at the delta each year, which has advanced over 3,300 feet in 25 years.

It was also estimated that the rate of ablation of the entire Glacier Bay ice cap, covering 500 square miles, has averaged from 20 to 25 feet per year more than the snow fall. During the past 25 years the ice plateaus, the surface of which was at 1,000 to 1,200 feet altitude, are now but 500 feet above sea level, and many of them will be gone within a decade or two owing to the more rapid rate of melting at the lower levels.

The discovery of two buried forests at different levels in the same gravel bank and another at tidewater with tree trunks rooted in undisturbed beds of top soil indicates definitely that there have been several periods when the Glacier Bay area was covered with luxuriant forests. In view of these facts, the writer referred to the reason for the present recession and past advances of the Glacier Bay ice cap as a fight for supremacy between the sun rays, which are melting down the surface of the ice, and the snow fall, which is responsible for its existence.

Glacier Bay borders the Pacific Ocean where the storms come from the south and southwest. As the area of perpetual snow is diminishing within the Glacier Bay area, the cold atmospheric conditions necessary for abundant snow fall are therefore lessening, and many of the storm clouds now pass over the Glacier Bay area and precipitate their moisture along the coast range 150 miles to the southeast where the areas of perpetual snow are increasing in size and colder atmospheric conditions prevail. That this is so is evident from the advance of the Taku, a Coast Range glacier, the face of which during the past 25 years has pushed forward about two miles, a half-mile of which has been added during the past two years.

Other causes such as the earthquake in 1899 and the effect of the Japan current and the local high tides have aided somewhat the recession in Glacier Bay, but these affect only a small portion of the ice cap fringe and the main cause of recession must be the sun rays which attack the entire surface.

The reasons for the several changes from the long periods of recession extending over several centuries to even longer periods of advance are not so clear. The recession usually continues until the glaciers have receded far up the mountain valleys and the exposed land areas have been overgrown by dense forests. These forests may have had their effect in helping to retain and protect the snow fall from the sun's rays at the lower elevations, thus giving a chance for the area of perpetual snow to increase, and gradually to alter the local atmospheric conditions so as to encourage more abundant snow fall and thus start a new cycle of glacial advance. The writer does not believe that the ice recession in Glacier Bay is connected with any general climatic cycle but that it is a local phenomenon recurring every few thousand years due to changes in local atmospheric conditions. (*Author's abstract.*)

HARRY FIELDING REID: *Glacier Bay 40 years ago.*—The speaker showed lantern slides of the glaciers of Glacier Bay in 1890 and 1892 and contrasted them with others made last summer. They showed enormous changes, three of them, the Muir, the Grand Pacific, and the Johns Hopkins having retreated about ten miles. The many old forests buried under thick deposits of gravels show that at no very long time ago the glaciers were markedly smaller than they are now; and that the great advance of 150 years ago was of short duration. (*Author's abstract.*)

MR. WRIGHT'S and MR. REID'S papers were discussed together by Messrs. W. O. FIELD, BURCHARD, CAPPS, COTTSWORTH, and MATTHES.

J. F. SCHAIRER and W. H. BRADLEY, *Secretaries.*

SCIENTIFIC NOTES AND NEWS

Under the provisions of the Economy Act, E. O. ULRICH, M. R. CAMPBELL, and F. C. SCHRADER of the Geological Survey were retired June 30.

By order of the President the following members of the Academy are exempted from the retirement provisions of the Act: WALTER HOUGH, National Museum; WILLIAM J. HUMPHREYS, Weather Bureau; CHARLES F. MARVIN, Weather Bureau; TIMOTHY W. STANTON, Geological Survey (temporary extension); LEONARD STEJNEGER, National Museum; C. DAVID WHITE, Geological Survey.

Obituary

Dr. GEORGE K. BURGESS, director of the Bureau of Standards, past president of the Washington Academy of Sciences, died of cerebral hemorrhage on July 2, 1932. He was born in Newton, Mass., Jan. 4, 1874. After graduating from the Massachusetts Institute of Technology, he studied at the Sorbonne in Paris. There he redetermined the value of the Newtonian constant of gravitation, receiving his doctorate in 1901 with highest honors. Dr. BURGESS entered the Bureau of Standards in 1903 and by his ability and application advanced steadily from assistant physicist to director of the Bureau. His first work was in the field of pyrometry. In 1913 he become chief of the metallurgical division. He was appointed director on April 21, 1923.

Dr. BURGESS was chairman of the National Research Council, a member of the National Advisory Committee for Aeronautics, of the National Academy of Sciences and of the Washington Academy of Sciences. He was the United States delegate to the seventh International Conference on Weights and Measures in Paris in 1927 and to the world Engineering Congress in Tokio in 1929; president of the National Conference on Weights and Measures; member of the Foreign Service and Engineering Commissions; director of the American Standards Association; honorary member of the American Foundrymen's Association; member of the American Institute of Mining and Metallurgic Engineers; past president of the American Society of Steel Treating, and the American Society for Testing Materials; member of the American Commission on the Annual Tables of Physical and Chemical Constants; member of the Optical Society of America, the American Physical Society, Philosophical Society of Washington, and the American Institute of Metals; fellow of the American Association for the Advancement of Science; honorary member of the Japanese Society of Mechanical Engineers; chairman of the Federal Specifications Board, the National Screw Thread Commission, and the Federal Fire Council.

DR. CHARLES WALLACE RICHMOND, associate curator of birds, U. S. National Museum, died in Washington May 19, 1932. Dr. RICHMOND was born in Kenosha, Wisconsin, Dec. 31, 1868. He became a page in the House of Representatives in 1881, joined the Geological Survey in exploration in Montana in 1888, and became ornithological clerk in the division of economic ornithology and mammalogy in the Department of Agriculture on his return. In 1894 he was appointed assistant curator of birds at the U. S. National Museum and in 1918 associate curator. He was a recognized authority on problems of ornithology.